GPM

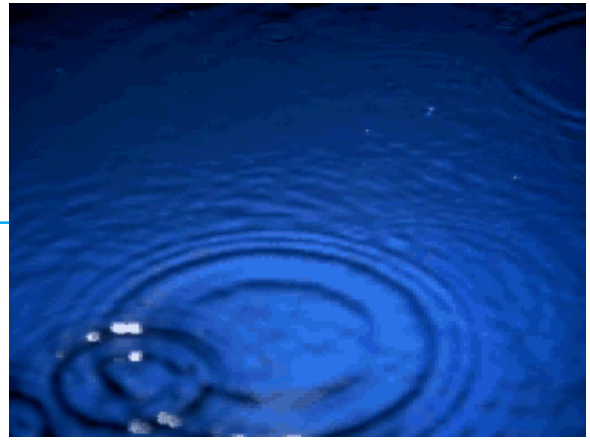
GLOBAL PRECIPITATION MEASUREMENT

Global Precipitation Measurement (GPM) Program Status

6th GPM International Planning Workshop

Annapolis, Maryland USA

November 6, 2006



Ramesh K. Kakar, Steven P. Neeck
NASA Headquarters

HEADQUARTERS

Water is fundamental to the life on Earth

Its transition between the gaseous, liquid, and solid states dominates the behavior of the Earth system

Precipitation converts atmospheric water vapor into rain and snow …

and is a central element of the global water cycle and the primary source of freshwater

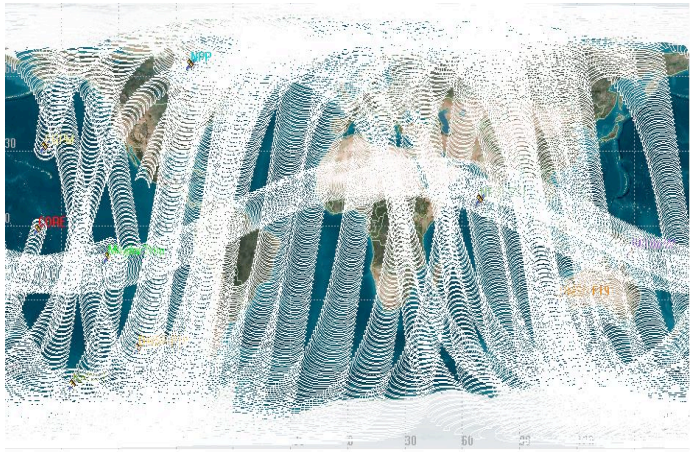
Accurate and timely knowledge of global precipitation is essential for

- *understanding the integrated weather/climate/ecological system*
- *managing freshwater resources*
- *monitoring & predicting high-impact natural hazard events*

GPM An international satellite mission to provide

uniformly-calibrated precipitation measurements every 2-4 hours around the globe

A science mission with integrated applications goals



GPM Science Objectives:

- *Advancing precipitation measurement capability from space*
  - active and passive remote-sensing techniques
- *Advancing understanding of global water/energy cycle variability and fresh water availability*
  - better measurement of the space-time variability
- *Improving weather forecasting skills*
  - more accurate & frequent instantaneous rain rates
- *Improving climate modeling and prediction capabilities*
  - better understanding of precipitation microphysics, surface water fluxes, & soil moisture storage
- *Improving prediction capabilities for floods, landslides, freshwater resources, and other hydrological applications*
  - improved temporal sampling spatial coverage

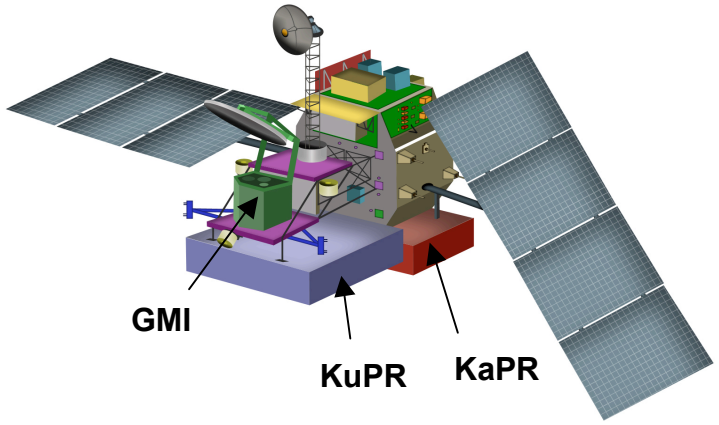
Role in Global Precipitation Measurements

- *GPM Core Spacecraft provides combined radar/radiometer measurements of 3-D precipitation structures and microphysical properties to serve as*

1) a precipitation physics laboratory for improved understanding of precipitation processes and retrieval algorithms and

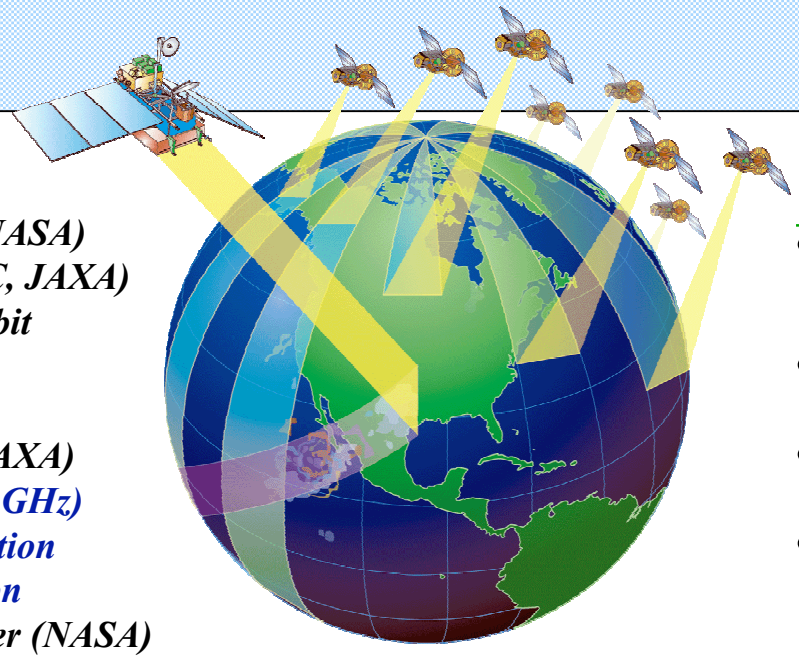
2) a reference standard for unifying measurements from a heterogeneous constellation of dedicated and operational satellites with passive microwave radiometers and sounders.

- *A NASA constellation satellite in a low-inclination orbit to improve real-time monitoring and prediction of hurricanes/typhoons*



GPM Reference Concept

- *Understand horizontal & vertical structure and microphysical properties of precipitation, and associated latent heating*
- *Train & calibrate retrieval algorithms for constellation radiometers*
- *Provide global coverage and temporal sampling to improve rainfall accumulations and real-time precipitation monitoring*
- *Extend scientific and societal applications*



Core Satellite

- *TRMM-like spacecraft (NASA)*
- *H2-A rocket launch (TBC, JAXA)*
- *Non-sun-synchronous orbit*
  - *~ 65° inclination*
  - *~407 km altitude*
- *Dual frequency radar (JAXA)*
  - *Ku-Ka Bands (13.6-35.5 GHz)*
  - *~ 4 km horizontal resolution*
  - *~250 m vertical resolution*
- *Multifrequency radiometer (NASA)*
  - *10.65, 18.7, 23.8, 36.5, 89.0, 166, 183.3 GHz*

Constellation Satellites

- *Pre-existing operational-experimental & dedicated satellites with PMW radiometers & sounders*
- *Revisit time*
  - *~ 2-4 hour at > 80% of time*
- *Sun-synch & non-sun- synch orbits*
  - *600-900 km altitudes*
- *A real-time hurricane monitor in a low-inclination orbit (TBC, NASA)*

Ground Validation Sites

- *Ground measurement & calibration*
- *Cooperative international partners*

Precipitation Processing System

- *Global precipitation products from input data provided by a consortium of cooperative international partners*

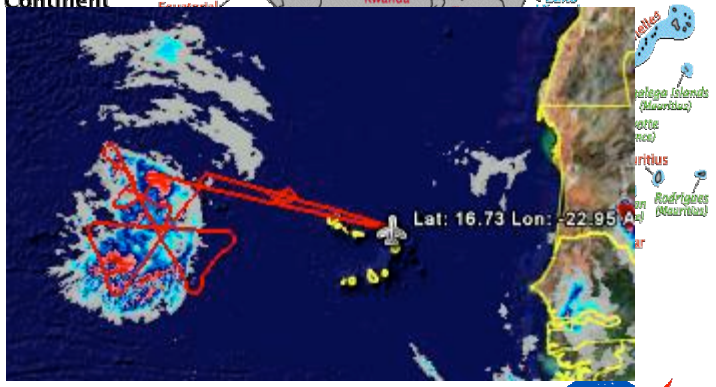
New Precipitation Science Team

- ***NASA selects a new Precipitation Science Team for FY 2007-09***
  - *Relation of precipitation to climate diagnostics*
  - *Retrieval algorithms and validation*
  - *Applications to hydrology and oceanography*
  - *Improvements in weather forecast capability*
  - *Education and outreach*

  - *127 proposals were received and evaluated*
  - *59 proposals were selected*
  - *Approximately $8.5 M/yr is expected to be available*

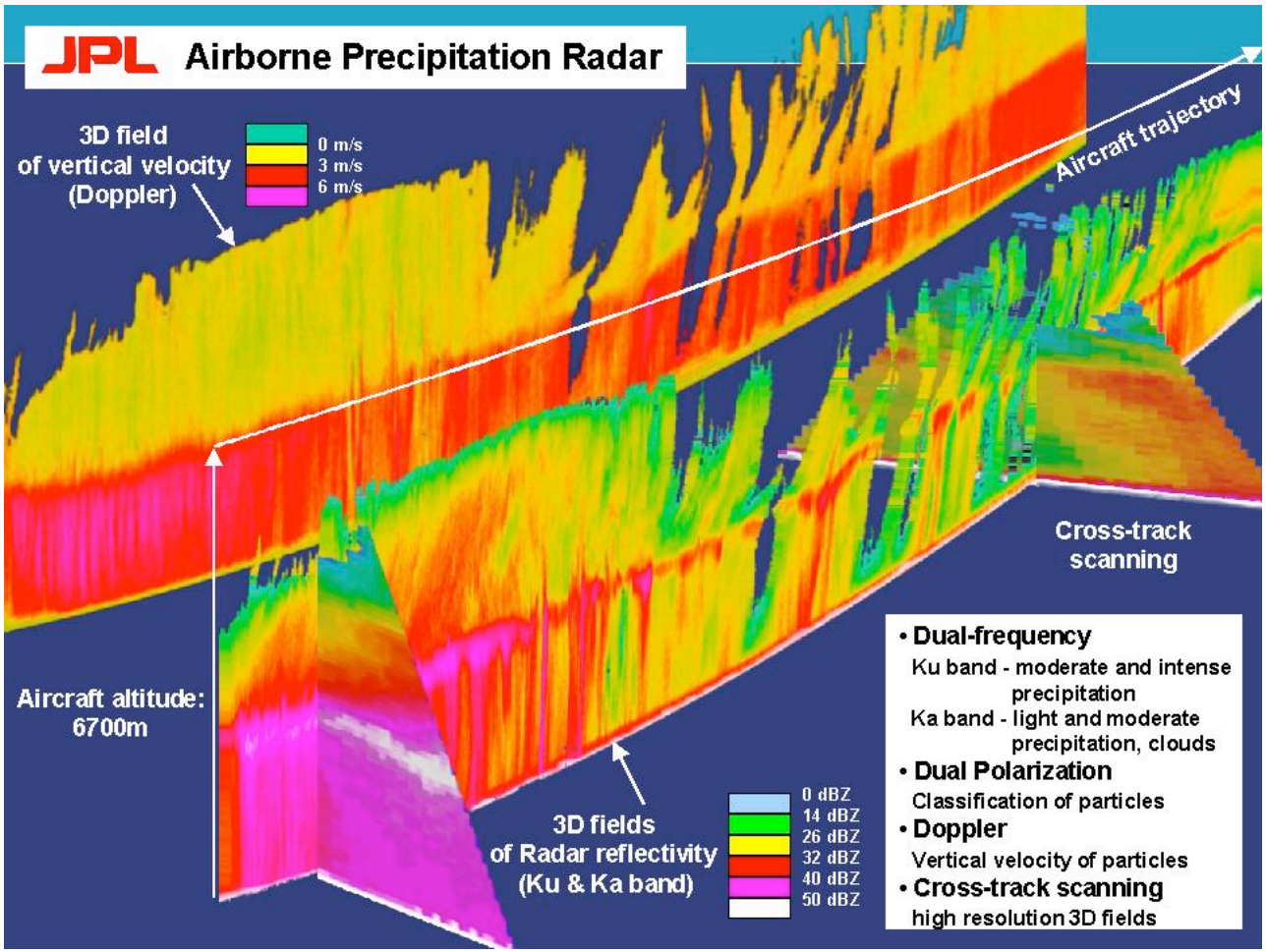
NAMMA (NASA African Monsoon Multidisciplinary Activities)

- *NAMMA-06 was a 4 week (start 8-15-06) field experiment involving DC-8 and ground radars and Leveraged off of the International AMMA experiment*
- *NAMMA-06 studied the downstream or oceanic evolution of African Easterly Waves (AEWs) and their relationship to tropical cyclogenesis*
- *The DC-8 carried a variety of active and passive remote sensors including a dual frequency precipitation radar and a microwave imager/sounder with "high frequency channels"*
- *The DC-8 was based at Cape Verde Island and two NASA weather radars were deployed at Cape Verde and Dakar, Senegal respectively*
- *Four of the seven AEWs studied became tropical storms (Debbie, Ernesto, Florence and Helene) while three fizzled out*



Airborne Dual-Frequency Radar (APR-2)

- ***PR-2 LO/IF module, real-time pulse compression and digital processing module were prototyped as airborne simulator, and will be flown on NASA DC-8 during NAMMA***

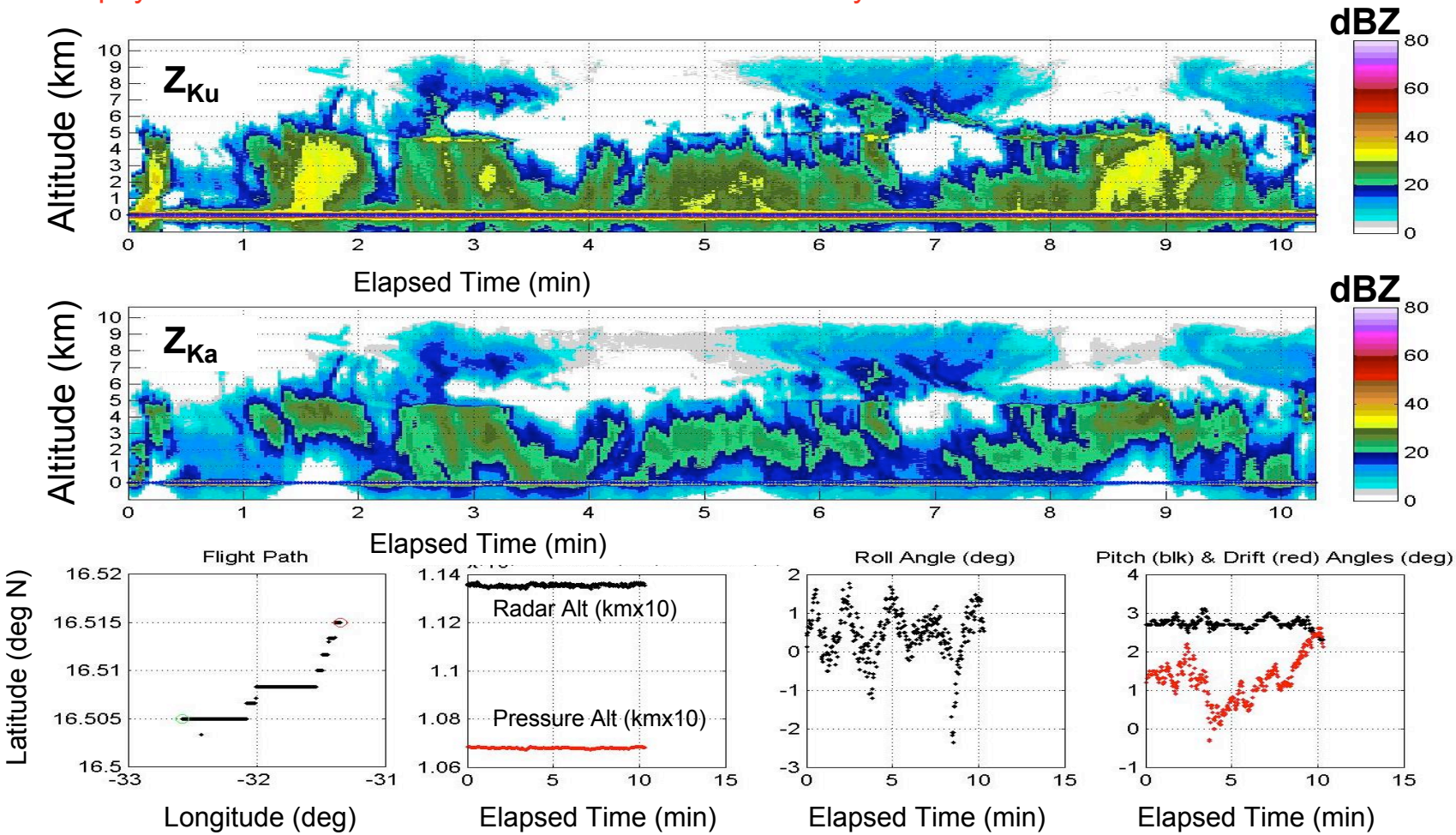


APR-2 Operation during NAMMA

- ***APR-2 Operated for ~34 hours during 16 flights.***
- ***APR-2 was operated mostly when in presence of precipitation or detectable cloud particles. Some clear air surface backscatter was acquired mainly in conjunction with dropsondes for calibration purposes.***
- ***Ku- and Ka-band reflectivity, LDR and Doppler velocity generated approximately 44GB of raw radar data.***
- ***APR-2 real-time output was used to provide immediate feedback to Mission Science (e.g., presence of precipitation, large ice crystals, melting layer etc.).***
- ***APR-2 quicklook images were generated in general within 24 hours.***
- ***Preliminary calibration of reflectivity measurements is completed.***
- ***Calibration of Linear Depolarization Ratio is ongoing.***

APR-2 Dual Frequency measurements of cloud and precipitation

- Reflectivity factor at Ku- and Ka- band from APR-2 measurements.
- Preliminary calibration: estimated uncertainty +/- 3dB. Final calibration is expected to be within +/- 1dB.
- APR-2 operated during 3 microphysics modules where the DC-8 penetrated a precipitating system at several altitudes. The radar data from these modules will be used jointly with in situ probe measurements (in collaboration with A. Heymsfield) to study the characteristics of the melting layer of precipitation and microphysical characteristics of stratiform and convective systems.



HAMSR Measurements

Direct measurements:

- **Brightness temperatures in 25 channels**
- **Three sounding bands**
  - T(z) @ 50 GHz - 8 ch's
  - T(z) @ 118 GHz - 10 ch's
  - q(z) @ 183 GHz - 7 ch's

Derived measurements:

- **Vertical profiles**
  - Temperature profiles
  - Water vapor profiles
  - Liquid water profiles
  - Surface to flight altitude
  - 2 km layers
- **Rain rate**
- **Convective intensity**

Chan #	Center freq. [GHz]	Offset [GHz]	Bandwidth [MHz]	Wt-func. Peak [mb or mm]
I-1	118.75	-5.500	1500	Sfc/[30 mm]
I-2	"	-3.500	1000	Surface
I-3	"	-2.550	500	Surface
I-4	"	-2.050	500	1000 mb
I-5	"	-1.600	400	750 mb
I-6	"	-1.200	400	400 mb
I-7	"	±0.800	2x400	250 mb
I-8	"	±0.450	2x300	150 mb
I-9	"	±0.235	2x130	80 mb
I-10	"	±0.120	2x100	40 mb
II-1	50.30	0	180	Sfc/[100 mm]
II-2	51.76	0	400	Surface
II-3	52.80	0	400	1000 mb
II-4	53.596	±0.115	2x170	750 mb
II-5	54.40	0	400	400 mb
II-6	54.94	0	400	250 mb
II-7	55.50	0	330	150 mb
II-8	56.02 56.67	0	270 330	90 mb
III-1	183.31	-17.0	4000	[11 mm]
III-2	"	±10.0	2x3000	[6.8 mm]
III-3	"	±7.0	2x2000	[4.2 mm]
III-4	"	±4.5	2x2000	[2.4 mm]
III-5	"	±3.0	2x1000	[1.2 mm]
III-6	"	±1.8	2x1000	[0.6 mm]
III-7	"	±1.0	2x500	[0.3 mm]

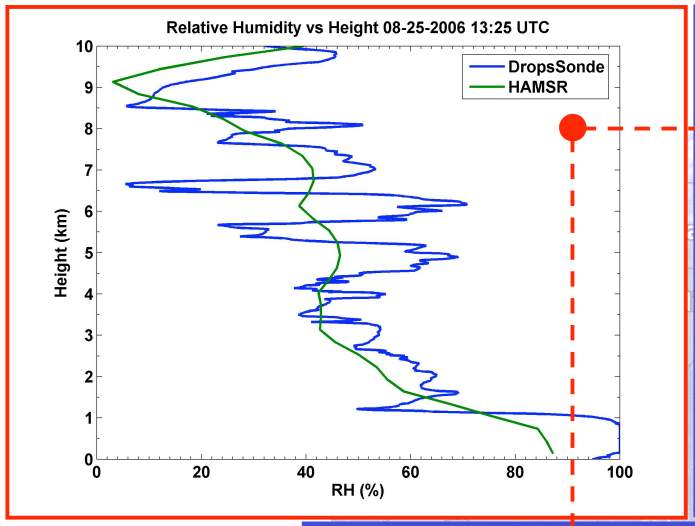
Bjorn Lambrigtsen, Principal Investigator
Jet Propulsion Laboratory/California Institute of Technology

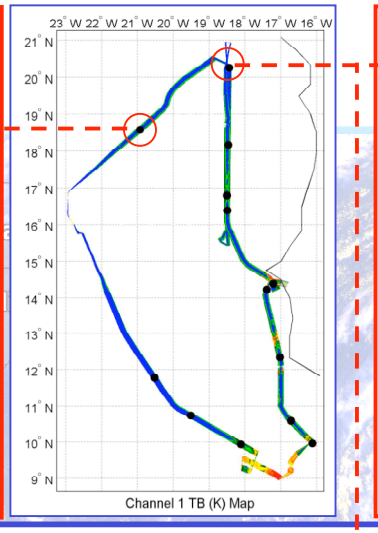
High Altitude MMIC Sounding Radiometer

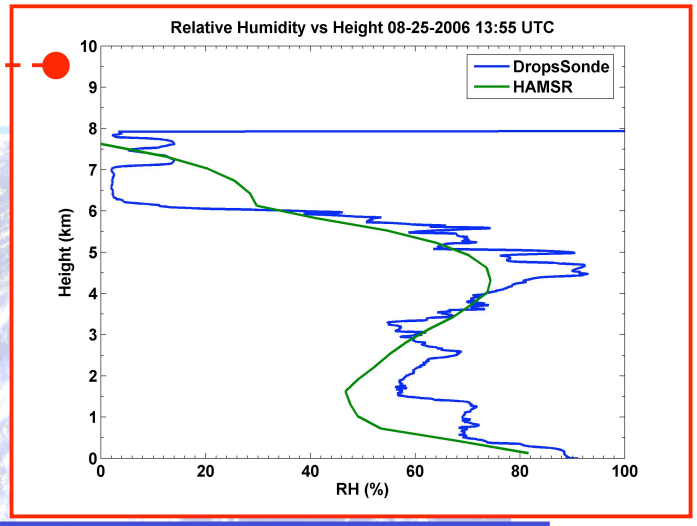
Water Vapor Observations with HAMSR during NAMMA

Comparison with dropsondes

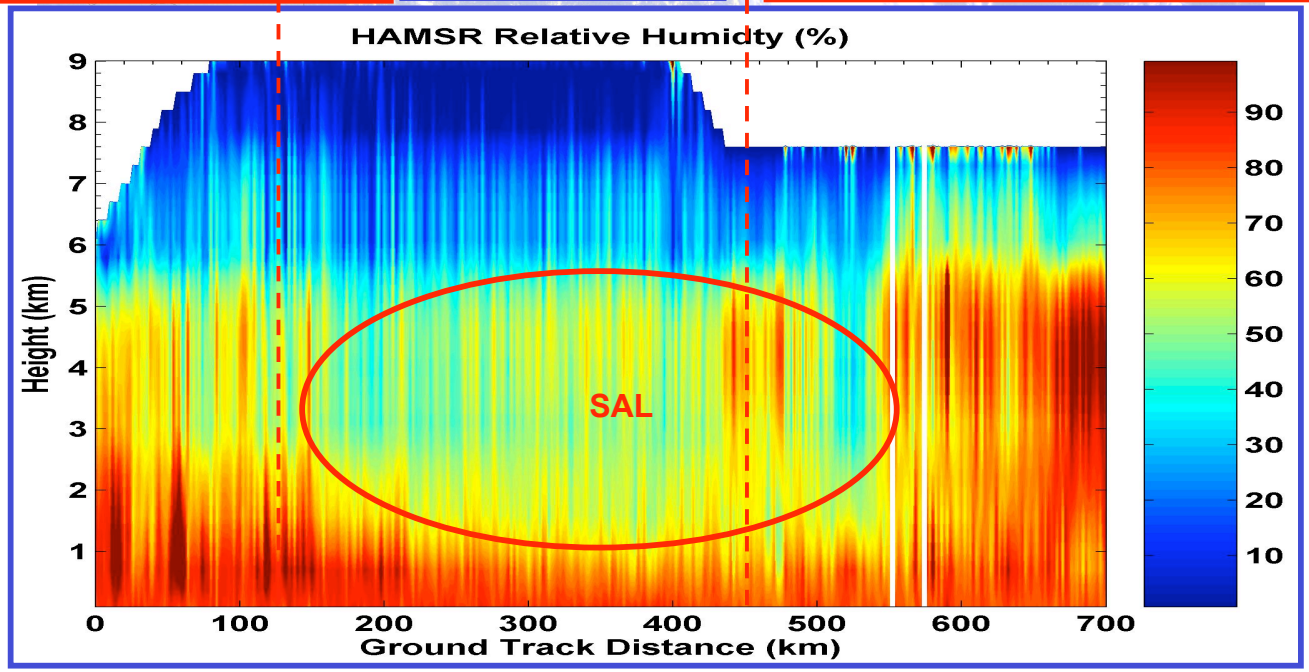
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California







HAMSR shows good agreement with dropsondes



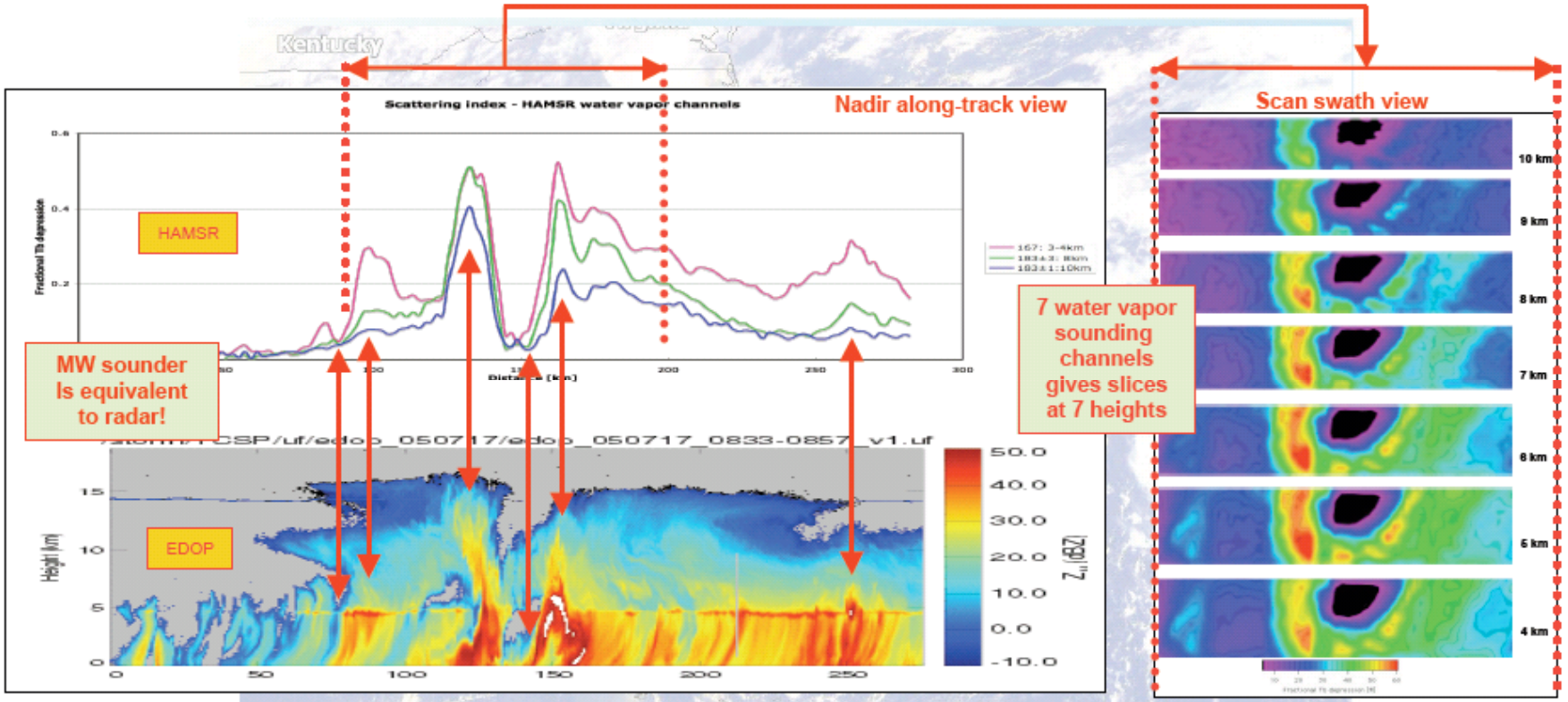
Bjorn Lambrigtsen, Principal Investigator
Jet Propulsion Laboratory/California Institute of Technology

Scattering Observations with HAMSR during TCSP

Comparison with doppler radar (EDOP)

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Vertical slicing through a hurricane



Future products under development:

- Ice water path & vertical distribution
- Rain rate - vertically resolved
- Convective intensity
- Microphysical properties

Bjorn Lambrigtsen, Principal Investigator
Jet Propulsion Laboratory/California Institute of Technology

Status (1/2)

- ***Technical***
  - *Formulation Phase (Phase B) continues with emphasis on preliminary design*
  - *GPM Microwave Imager development proceeding*
    - *PDR scheduled for November 13-17, 2006*
  - *Joint industry and government implementation approach for Core Spacecraft*
    - *7 month multi-vendor (Orbital Sciences Corporation and General Dynamics) Avionics package study completed in September 2006*
    - *RFO and contract award scheduled for later in 2007*
    - *PDR scheduled for March 2008*
  - *Precipitation Processing System (PPS)*
    - *WindSat 1C data product in regular production (an important prototype for GPM era intercalibration and partner radiometer data inclusion)*
    - *Routinely producing 1C products for TMI, SSMI, AMSRE, and SSMIS*
- ***Budget***
  - *NASA's FY2007 proposed budget funds GPM at $24M in FY2007*
    - *Agency currently operating under Continuing Resolution*
    - *Core Spacecraft LRD in 2013 and Constellation Spacecraft LRD in 2014*
    - *FY2008 budget process and NRC Decadal Survey prioritization may influence LRDs*

Status (2/2)

- ***International Partnerships***
  - *Brazil has included a constellation satellite in its 2005-2014 National Space Activities Plan (PNAE)*
    - *A joint study agreement is being developed as a result of the December 2005 NASA/AEB Bilateral Group meeting*
  - *GPM identified in GEO2006 Task (AR-06-10) and CEOS Precipitation Constellation pilot study*
- ***Domestic Partnerships***
  - *NPOESS Program has been certified in accordance with Nunn-McCurdy DoD regulatory requirements*
  - *NRC Committee on the Future of Rainfall Measuring Missions released* ***NOAA's Role in Space-Based Global Precipitation Estimation and Application***
- ***NRC Decadal Survey of Earth Science and Applications from Space***
  - *Final report expected by December 2006*
  - *Input for Earth Science Roadmap in Science Plan*
- ***NASA Science Plan***
  - *Submission to Congress planned in December 2006 with update by mid-2007 with revised Earth Science Roadmap*

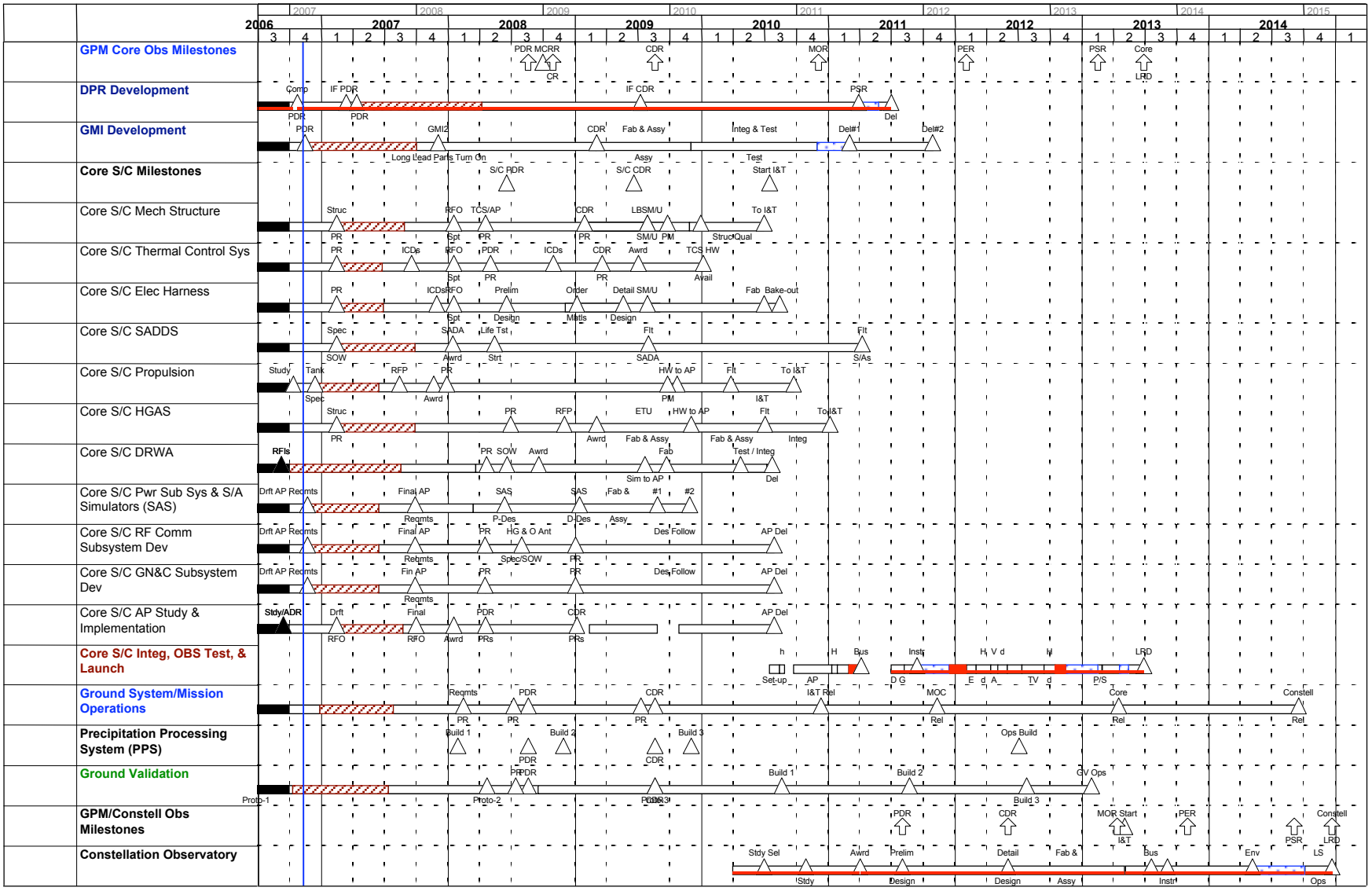
Constellation Reconfiguration

- ***NPOESS Nunn-McCurdy restructuring resulted in reduced coverage/sampling***
  - *C1 and C2 LRDs delayed*
  - *3 orbital planes reduced to 2*
  - *CMIS deleted from C1 and delayed to C2 (2016)*
  - *CMIS terminated and recompeted (Reduced channel set/antenna size?)*
  - *No mid-morning conical scan microwave radiometer data after F18 or F20 (2012 or 2014)*
- ***Alternative microwave data sources (e.g. cross-track scanning sounders) are a mitigation***
  - *Sounder retrievals over land with HF water vapor channels are closer to PR than conical scanning imagers without HF between 1-10 mm/h*
  - *Use of AMSU-B, MHS, and ATMS (on POES, METOP, NPP, and C1) improves global average revisit times*
  - *Additional data streams have no impact on Precipitation Processing System (PPS)*

Near-Term Goals

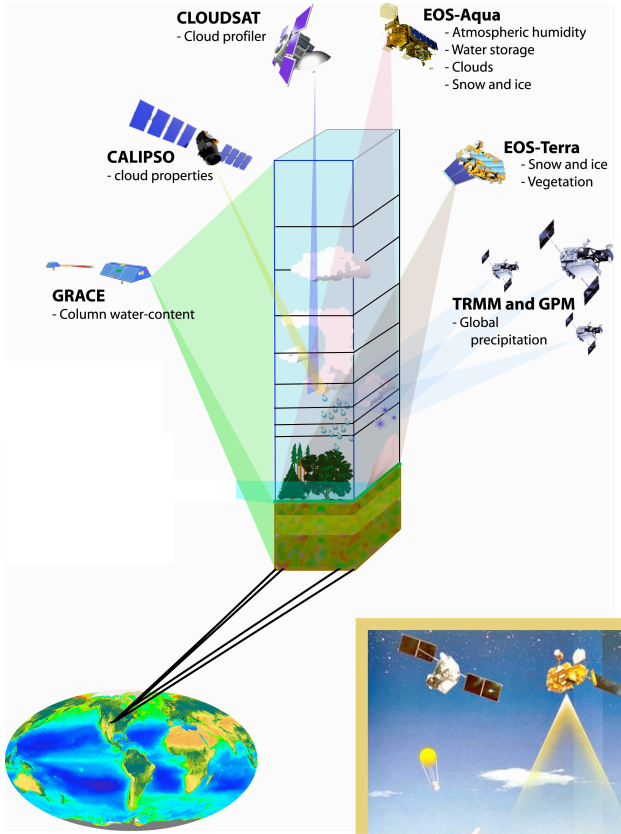
- ***Complete mission preliminary design – FY08***
  - *Satellites, instruments, and ground system*
- ***Confirm Mission – FY08***
  - *Formal approval to implement*
- ***Mature International Partnerships – FY07-08***
- ***Mature Inter-Agency Partnerships – FY07-08***

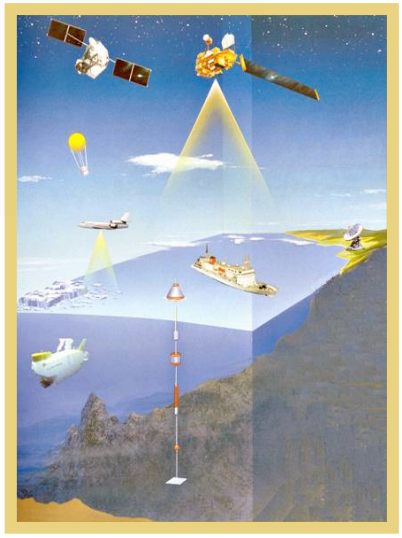
Master Schedule



Backup

GPM Global Water and Energy Cycle Observation Strategy





GPM

- ***Flagship mission for NASA's Global Water and Energy Cycle (GWEC) research and applications***
- ***Important contribution to the U.S. Climate Change Science Program & the U.S. Weather Research Program***
- ***Building on***
  - ***the success of TRMM***
  - ***NASA/JAXA capabilities in precipitation measurements from space***
  - ***national and international partnerships in satellite constellation formation and ground validation***
- ***Candidate component of the emerging Global Earth Observing System of Systems (GEOSS), an international effort to provide comprehensive, long-term, and coordinated observations of the Earth***

President's FY 2007 Budget Request*

Theme:	Earth-Sun System
Program:	Earth Systematic Missions
Project In Formulation:	Global Precipitation Mission (GPM)

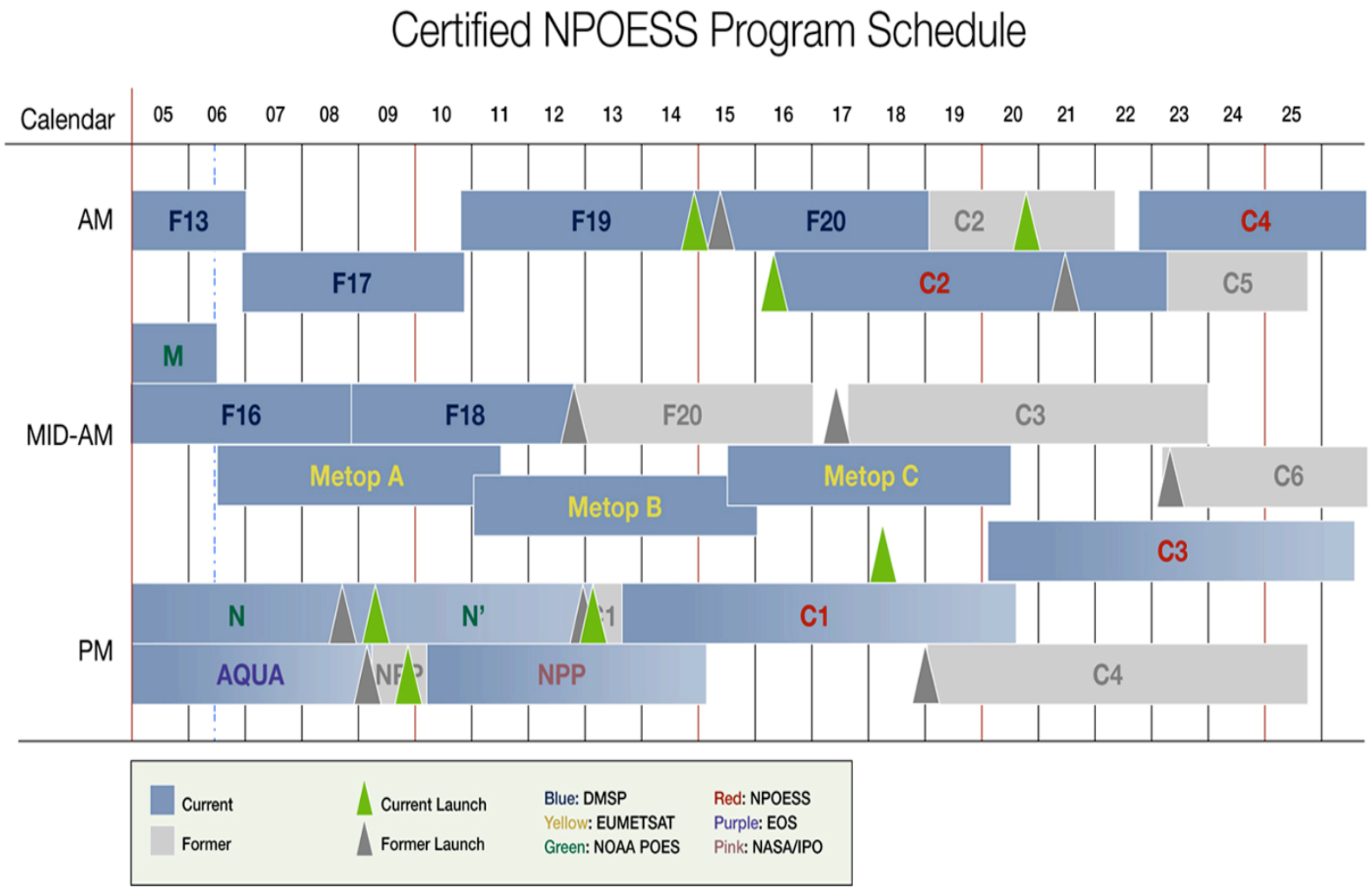
President's FY 2007 Budget Request (Dollars in Millions)

Global Precipitation Mission (GPM) (Formulation)	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011
FY 2007 OMB Submit	26.5	23.2	24.2	25.4	117.8	121.6	140.1
Changes from FY 2006 Request	0.2	-0.7	-19.7	-74.5	-36.8	-6.9	

Projects in Formulation are not mature in their development process and cost estimates are SUBJECT TO CHANGE as the project matures.

*From NASA FY 2007 Budget Request – SAE SMD 4-12, February 2006, http://www.nasa.gov/pdf/142458main_FY07_budget_full.pdf.

Certified NPOESS Program Schedule



NPOESS Nunn-McCurdy Certification Content Reductions

NPOESS Nunn-McCurdy Certification Content Reductions

NPOESS Instruments	NPP	EARLY-AM		MID-AM			PM	
		C2	C5*	C3	METOP	C6	C1	C4*
VIIRS	✓	✓	✓	✓	AVHRR	✓	✓	✓
CMIS*		✓	✓	✓		✓	✓	✓
CrIS/ATMS	✓	✓	✓		IASI/ATMS		✓	✓
SESS*		✓	✓	✓	SEM	✓		✓
OMPS*	✓						✓	✓
APS							✓	✓
TSIS		✓	✓					
CERES/ERBS							CERES	ERBS
ALT		✓	✓					
Survivability		✓	✓	✓		✓	✓	✓
SARSAT		✓	✓	✓	✓	✓	✓	✓
ADCS		✓	✓		✓		✓	✓

Remains Intact
Reduced Coverage
Deleted
Reduced Capability

*CMIS to be redefined as a less capable, less expensive sensor
*SESS is cancelled and the existing SEM will be substituted
*OMPS Limb Subsystem is cancelled and the Nadir Subsystem is maintained
*C5 becomes C4 Post-Nunn-McCurdy
*C4 becomes C3 Post-Nunn-McCurdy